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Assessment of Atlantic Salmon (Salmo salar L.) Habitat in the Sackville River, N.S., 1986

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ASSESSMENT OF ATLANTIC SALMON (Salmo salar L.) HABITAT IN THE SACKVILLE RIVER, N.S., 1986

February 1990

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ABSTRACT

Cameron, J.D. 1990. Assessment of Atlantic salmon (Salmo salar L.) habitat in the Sackville River, N.S., 1986. Can. MS. Rep. Fish. Aquat. Sci. 2059: 39 p.

In 1986, the main stem of the Sackville River and the Little Sackville River were surveyed to measure and evaluate potential Atlantic salmon habitat. Data on obstructions, water temperatures, water chemistry and other factors affecting fish life were collected. A total of 600,000 m^2 of river area suitable for salmon was measured, of which 130,000 m^2 was considered of high quality. This information, in conjunction with that of previous bio-assay and electrofishing surveys, was used to estimate the potential of the Sackville River system for natural production and the possible enhancement with hatchery stocks.

Key words: Atlantic salmon, Sackville River, Little Sackville River, salmon habitat, habitat quality.

Résumé

Cameron, J.D. 1990. Assessment of Atlantic salmon (Salmo salar L.) habitat in the Sackville River, N.S., 1986. Can. MS. Rep. Fish. Aquat. Sci. 2059: 39 p.

En 1986, on a examiné le bras principal de la rivière Sackville et la rivière Little Sackville afin de mesurer et d'évaluer l'habitat éventuel du saumon. A cette occasion, on a recueilli des données sur les obstacles, sur les températures et la chimie de lèau ainsi que sur d'autres éléments influencant la vie des poissons. On a mesuré au total 600 000 m^2 d'habitat convenant au saumon, dont 130 000 m^2 jugés de haute qualité. On s'est servi de l'information ainsi acquise et de celle qui avait été obtenue lors de bio-essais et d'études de détection par la pêche éelectronique afin d'estimer les possibilités qu'offre la rivière Sackville pour la produciton naturelle et l'empoissonnement au moyen de stocks d'élevage.

Mots-clés : Saumon de l'Atlantique, rivière Sackville, rivière Little Sackville, habitat du saumon, qualité de l'habitat.

INTRODUCTION

The construction of a dam in the 1850s, 4 km upstream from the mouth, probably began the process which led to the drastic decline of Atlantic Salmon (Salmo salar) stocks in the Sackville River, Nova Scotia. One Bedford resident of 1848 reported angling 19 salmon in one day, the smallest of which exceeded 8 kg in weight. After the dam was built, neither angler nor commercial fisherman found it worthwhile to fish in the area. A fishway was built for the dam in 1867, but no improvement was noted, probably because of increased pressure from poaching (Dunfield 1985). Records indicate that 33 Atlantic salmon (grilse) were angled between 1944 and 1958, with 12 of these recorded in 1958. Since then, there have been occasional reports of salmon angled. Electrofishing confirmed the presence of juvenile Atlantic salmon in 1979 (Table 8), but none were found in 1985 in upstream areas (Table 10). During the summer of 1986, a survey was completed on the potential of this river system for supporting Atlantic salmon, the results of which are given in this report.

GENERAL DESCRIPTION OF THE WATERSHED

The Sackville River drains an area of 146 km^2 in the central region of mainland Nova Scotia. The river originates 152 m above sea level at Mount Uniacke in Hants County in a poorly drained, boggy area; flows southeast for approximately 30 km, and empties into the Bedford Basin on the Atlantic Coast. As the river flows south, it encounters increased housing, industrial, recreational, and commercial developments. The major tributary, the Little Sackville River, flows south for 9 km through the town of Middle Sackville and empties into the main Sackville River 4 km from the head of tide. The watershed contains 18 ponds and lakes: Duck and Horse Ponds, Pentz, Yellow Lily, Lewis, Drain, Little Springfield, Tomahawk, Beaver (tributary to Tomahawk), Beaver (on Thompson run), McCabe, Bottle, Webber, Marsh, Sandy (on Thompson run), Sandy (on Hammonds Plains Road), and Little and Feely Lakes on the Little Sackville River. Stillwaters and bogs are plentiful upstream of Webber Lake because of poor drainage. Little Deadwater is the largest stillwater. Vegetation around the upper tributaries and bogs is a tangle of stunted black spruce (Picea mariana), alders (Alus rugosa), and various bog and barren shrubs. At higher elevations, much of the forest land has been extensively burnt or logged, but scattered areas support a second growth forest of balsam fir (Abies balsamea), white spruce (Picea glauca), and red maple (Acer rubrum). Most old farms now support second growth forest, with only a few open fields remaining. Gravel pits are numerous.

The large stillwater upriver of Lewis Lake is used extensively for recreation, including boating, swimming and fishing, by residents of a nearby trailer park and others. Highways 1 and 101 cross the river upstream of Lewis Lake, and Highway 102 crosses downstream from the town of Lower Sackville. The main river is crossed by six other highways and two railroad bridges. The Little Sackville River is crossed eight times by roads and highways. A major municipal landfill site with a pumping station and sewage treatment ponds exists downstream of Lewis Lake. High voltage transmission lines cross the stream at two locations.

The two largest lakes of the system, Tomahawk and McCabe, are relatively undeveloped. Extensive logging has occurred in the past around both lakes and some clear-cutting is now evident. Tomahawk Lake is accessible by a dirt road and is utilized to some extent for boating and fishing. McCabe Lake has three small camps near the outlet and is utilized by the Boy Scouts as a camping area. McCabe Lake is accessible only by a private woods road. Webber Lake is being developed as a residential area, with new homes being constructed on the left bank. A large sawmill occurs downstream of the Lucasville highway at the mouth of Webber Lake. Some river water is diverted to a small pond used to hold logs for the sawmill. For over a kilometer downstream of the sawmill, Highway 101 separates the river from a rapidly expanding residential area of Middle Sackville. A large gravel pit has been excavated where the river swings west, away from residential area. This pit is apparently now unused, but previous gravel removal has caused much damage from river diversion and severe bank erosion. This pit has also been used as a garbage dump and a play area for dirt bikes and all-terrain vehicles (ATVs). The river immediately upstream of the gravel pit is now torrential with extensive bank erosion and uprooted trees. One small farm downstream of the gravel pit has road access (gated) to the river and a pasture extending down to the riverbank where cattle are watered. A high left bank diverts the river from a residential area and a page wire fence around DND property now hinders access to the river down as far as the mouth of the Little Sackville River. From the Little Sackville River down to the mouth, the river flows through a highly residential and commercial area with a continuous system of highway overpasses, apartment and office buildings, shopping centers, picnic areas, parking areas, garages and lawns. A federal fish hatchery at the mouth of the river was closed in 1961. The site was developed by the town as a small park in the mid-1970s.

The Little Sackville River originates 92 m above sea level from Little and Feely lakes in the Beaverbank area of Halifax County. Scattered residential housing and a sawmill exist in the headwaters area. As the river flows south, it passes through the most highly commercialized and rapidly expanding area of the town of Middle Sackville. Ice jams occur frequently in the lower sections of the river with heavy

equipment being used in the river to break the jams and prevent flooding. Both pH and conductivity are high, as are pollution and siltation.

SALMON HABITAT

EVALUATION METHODS

During August 5-8, September 10 and October 29, the main stem of Sackville River from the head of tide to the highway bridge at East Uniacke, as well at the Little Sackville River, was surveyed by foot and canoe. Beginning at the head of tide, 100 m long sections were measured off with an optical tape measure. Three widths were measured within each section and averaged to estimate mean width. Five depth measurements were made at each width. For each section, estimates were made of the percentage of substrate components (silt, sand, gravel, cobble, boulder and bedrock) and of water surface components (riffle, run, flat, pool and stillwater). Areas and depths of pools were measured separately. Definitions of these habitat components and their categorization as nursery or spawning habitat were taken from Gray et al. (1982) and are given in Appendix A. Notes were taken on access, pollution, water temperature, shade, cover or any other factors believed to influence adult or juvenile populations of Atlantic salmon.

No attempt was made to measure tributaries or extreme headwater areas. Most of these areas are stillwater and bogs, with occasional very small, poor quality runs, with poor access. It is considered doubtful that these areas would contribute significantly to salmon production on the Sackville River system. However, production estimates from this survey should be considered minimal for this river system.

The quantity and quality of Atlantic salmon habitat fish species occurrence, physical and chemical parameters, and bio-testing results are summarized in (Tables 1-11). Appendices A to E define substrate types, give detailed measurements of substrate and water surface characteristics as well as comments on each 100 meter section. Gravel permeability measurements at two locations are summarized in Tables F-1 and F-2.

LOCATION

Estuary to Junction With Little Sackville River

The section of the main Sackville River between the estuary and Little Sackville River receives the highest burden of pollution and siltation of any portion of the river from the commercial and industrial development of Middle Sackville and Bedford. The area contains 26,800 m^2 or almost 5 percent of the good-to-fair nursery potential of the system. The remaining 33,100 m^2, approximately 6 percent of total nursery area, is of marginal value for Atlantic salmon (Table 1).

This section contains almost 16 percent of the system's total of good spawning area (Table 1). Unfortunately, most of the spawning area in this section receives discharge from the Little Sackville River with its associated high silt loads and pollution. Consequently, low egg survival can be expected. Gravel compaction in many areas is high (Appendix E). This area could benefit from gravel cleaning, but benefits would probably be short lived. Wild juvenile salmon were collected in this area in 1979 (Table 6).

A large, shaded stillwater near the mouth of the Sackville River could provide good holding for ascending adults. Unfortunately, the proximity of developed areas and human population would subject fish to high exploitation, whether legal or illegal. Summer water temperatures and pollutant levels would be high in this area.

Mouth of Little Sackville to Webber Lake

The area between Little Sackville and Webber Lake has the highest potential for Atlantic salmon production. It contains 72,050 m^2 of fair-to-good nursery, which is over 12 percent of the total potential river nursery area (Table 1). This section is less disturbed by the proximity of development, which impacts the river only in the upper and lower portions. Pools are scarce and small. A small, well-shaded stillwater near the center of this section should provide adequate holding for adults.

Approximately 60 percent of the total available spawning area is within this section (Table 1). The riverbanks are more stable than in the previous section, and the streambed would benefit more from gravel cleaning. Stabilization of the riverbanks, particularly the upriver section, and clearance of debris and windfalls would improve the potential of this section to support Atlantic salmon. Development in the upper portion of this section produces siltation and some sawdust enters the stream from the sawmill.

A small falls below Heflers sawmill is not a barrier to salmon migration, except during very low water conditions.

This area would generally be suitable for stocking smolt, fall fingerlings, or unfed fry in the absence of a native population.

Webber Lake to the Number 1 Highway

Between Webber Lake and Highway 1, a 700 m section of stream provides a small amount of nursery area and some scattered spawning area (Table 1).

Upriver of McCabe Lake exists a series of stillwaters of various lengths with

short runs in between. Runs are generally very rough, with boulders and bedrock, and are generally well shaded. Although this is the longer section, it contains only 4 percent of the fair-to-good nursery area for juvenile salmon (Table 1). The remainder of the area is mostly stillwater. Spawning gravel is very scattered. Pools are generally shallow, but some of the larger stillwaters are deep and would provide adequate holding for adults. A small falls in the lower portion is not a barrier except at low flows.

This area might be suitable for fall fingerling stocking. The extent of utilization of stillwaters by fall fingerlings is undetermined. Unless stillwaters are utilized, production in this section could be limited.

No evidence was found of pollution from the municipal landfill site existing in the upper part of this drainage, which has pumping and sewage treatment facilities.

Highway 1 to East Uniacke Raod

The stream area upriver of Highway 1 consists of one large stillwater (Little Deadwater) and a series of small stillwaters with very short connecting runs. Currents in the runs are generally slow and the stream bottoms are composed of large boulders and bedrock. The river-banks are a jumble of alders and coarse shrubs, which makes access difficult. This area contains only 0.8 percent of the fair nursery area (Table 1). Spawning gravel is almost non-existent. This area has little potential for natural Atlantic salmon production but some of the stillwaters might be utilized by stocked fall fingerling.

Little Sackville River

Unless steps are taken immediately to prevent further degradation of habitat and an effort made to restore lost habitat, the Little Sackville can be written off for Atlantic salmon production. Electrofishing in 1985 (Table 10) revealed no fish species and the lower reaches of the river may be unsuitable as fish habitat. The water is heavily polluted and siltation is severe. If these and associated problems are corrected, use could be made of the 35,200 m^2 of nursery area in this river (6.3 percent of the total Sackville River system nursery area), of which over half is of fair-to-good quality. Spawning gravel is very scattered and contributes less than 10 percent to the Sackville River total (Table 1). No pools are present.

A major clean-up and appropriate control of the adverse effects of municipal development are necessary if the Little Sackville River is to be restored for use by Atlantic salmon. Stocking of Atlantic salmon should not be considered until further surveys, including bioassay, have indicated that suitable conditions exist.

BIOASSAY

In 1985, the suitability of the Sackville River for Atlantic salmon was tested by bioassay. On April 22, cages containing 120 hatchery smolts from the Mersey Fish Culture Station (age 1+, LaHave River stock) were placed in the river for six days. The test area was downstream of Webber Lake and upriver of the confluence of the Little Sackville River. The caged fish were checked daily and water temperature and pH was recorded (Table 10).

At the end of six days, no mortalities had been observed and the fish gave no indication of abnormal stress. All the caged fish were then anesthetized, weighed, measured for fork length, and released into the river (Table 11).

The probable presence of effluent from a settling pond from a housing development at Middle Sackville, which raised the pH of the water means that the results from these tests can not be considered typical. A minimum pH reading of 5.80 was recorded during the test, but downstream at Webber Lake, the pH was 5.45, which is more typical of the river. Similar tests on the Liscomb River and West River, Sheet Harbour indicate that increasing stress and death occurs to hatchery smolts as pH values drop below 5.0 (Cameron, unpublished data). Farmer et al. (1980) also found high mortality occurring as pH values decreased below 5.0.

FISH SPECIES

Electrofishing in 1979 (Table 8) collected 31 Atlantic salmon fry (age 0+) all below the confluence of the Little Sackville river, except for one fish. Electrofishing in 1985 (Table 10) in the upper sections of the river collected no salmon. In addition to Atlantic salmon the most numerous fish collected were American eel (Anguilla rostrata) and white sucker (Catostomus commersoni). Other less common species collected were Brook trout (Salvelinus fontinalis) Lake chub (Couesius plumbeus), Brown bullhead (Ictalurus nebulosus), Banded killifish (Fundulus diahanus) and Common shiner (Notemigonus crysoleucas). Lake surveys also collected (Table 5), Yellow perch (Perca flavescens), White perch (Morone americana) and Golden shiner (Notemigonus crysoleucas).

PREDATORS

Electrofishing in 1979 and 1985 collected American eels at all sites with the exception of Little Sackville River (Table 8 and 10). One great blue heron (Ardea herodias) was observed flying over an upstream stillwater. No mergansers (Mergus sp.) were seen near the estuary. Human activity and distance from rookery probably prevent large concentrations of cormorants (phalacrocorax auritus) in this

area. A pair of loons (Gavia immer) were seen on Webber Lake and a pair of black ducks (Anser rubripes) above McCabe Lake. Beaver (Castor canadensis) signs were scarce even in upstream areas, but a few old dams and workings were noted. Raccoon (Procyon lotar) tracks were seen in the mud on Little Sackville River. Domestic ducks and geese inhabit the lowest stillwater areas.

DISCUSSION

Salmon habitat in the Sackville River system has been severely damaged by 200 years of steadily increasing urban development. Returning runs of Atlantic salmon have declined from several hundreds of fish to extinction or near extinction today. Erosion, siltation, nutrient enrichment from domestic and industrial effluents, more fluctuating water levels, increased water temperature, and lower pH have adversely affected the suitability of this river system for Atlantic salmon. Some of these problems, particularly low pH, are more serious than others and are not easily corrected. Until they are, the Sackville River will remain a marginal habitat for Atlantic salmon.

Even with a major clean up effort, natural production in the Sackville River cannot be expected to produce more than a small self-sustaining run of Atlantic salmon. The area of good and fair salmon nursery (128,759 m^2) shown in Table 1 could produce 5,150 smolts, assuming a production rate of 4 fish per 100 m^2 (Elson 1975). Areas of marginal production (394,406 m^2) might produce 4,000 smolts at a rate of 1 fish per 100 m^2. Potential production from the Little Sackville River would be about 1000 smolts from 21,030 m^2 of potentially good-to-fair nursery and from 14,170 m^2 of marginal nursery habitat. Given a conservative return rate of 3-6 percent from approximately 10,000 smolts, a return of 300 to 600 adults might occur.

Restoration of a river damaged by 200 years of development will require a major effort. Plans to clean up existing areas of degraded habitat and to reduce present and future habitat degradation need to be formulated and enacted prior to or at least in conjunction with enhancement plans for the river. A stocking strategy using hatchery-reared fish should be worked out with consideration given as to how enhanced stock will be utilized by user groups. Acid precipitation is perhaps the least controllable environmental hazard in a watershed that is poorly buffered geologically. Acid water mitigation measures such as liming are not economically feasible on the longer term (Watt 1986). Permanent long-term solutions to this problem are international in scope and even if enacted may not show results for many years.

The Sackville River presents a challenging opportunity to redevelop an anadromous population of Atlantic salmon in close proximity to a highly populated urban area of Canada.

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Table 1. Estimated nursery and spawning areas in main sections of Sackville River, 1986.

Section	Area (m^2)[a]				
	Nursery			Spawning	
	Good	Fair	Marginal	Good	Marginal
Mouth to junction of Little Sackville River	21,150 (3.8)[b]	5,650 (1.0)	33,100 (5.9)	13,700 (2.5) [15.6][c]	7,500 (1.3) [8.6]
Junction Little Sackville to Webber Lake	55,350 (9.9)	16,700 (3.0)	23,265 (4.2)	28,250 (5.1) [32.1]	24,800 (4.4) [28.2]
Webber Lake to #1 Highway	21,600 (3.9)	3,800 (0.7)	303,100 (54.3)	4,450 (0.8) [5.1]	8,378 (1.5) [9.5]
#1 Highway to East Uniacke Road	400 (0.1)	4,109 (0.7)	34,941 (6.3)		400 (0.1) [0.5]
Little Sackville River	15,940 (2.9)	5,090 (0.9)	14,170 (2.5)		500 (0.1) [0.6]

[a] Areas do not include lake surface.
[b] Percentage of total habitat suitable for nursery and spawning in each section is indicated within brackets.
[c] Percentage of total spawning area present in each section is indicated within square brackets [].

Table 2. Summary of estimated stream habitat characteristics in selected sections of the Sackville River, 1986.

Item	Mouth to Junction Little Sackville R.	Little Sackville R. to Webber Lake	Webber Lake to #1 Highway	#1 Highway to East Uniacke Road	Little Sackville R.
Distance(m)[a]	3,500	6,100	12,000	6,700	5,100
Mean width(m)[b]	17.4	15.5	30.6	22.8	7.1
Stream area(m^2)[b]	59,900	93,315	328,500	39,450	35,200
Mean depth(cm)	105.2	46.9	112.9	83.9	12.6
Substrate %					
Silt	22	9	2	33	23
Sand	17	10	4	11	11
Gravel	33	16	12	7	17
Cobble	17	30	36	22	29
Boulder	11	28	43	23	20
Bedrock	0	7	3	4	-
Water type %					
Riffle	38	62	27	13	55
Run	28	25	10	2	12
Flat	10	1	4	5	30
Stillwater	24	12	59	80	3
Pool (No)	1	8	9	4	0

[a] Includes lakes.
[b] Does not include lakes.

Table 3. Summary of physical features and water quality of lakes sampled during surveys of the Sackville River watershed.[a]

Lake	Surface elevation (m)	Surface area (ha)	Shoreline length (m)	Maximum depth (m)	pH	Conductivity (mhos/cm)	Date of survey
Pentz	152	37	3,400	5	7.0	58	Jul 78
Yellow Lily	115	4	1,300	N/A	N/A	N/A	N/A
Duck Pond	115	2	890	N/A	N/A	N/A	N/A
Bottle	110	12	1,703	6	6.3	38	Jul 78
Little Springfield	107	8	1,200	7	4.5	340	Jul 78
Lewis	107	21	3,100	2	6.0	60	Jul 78
Tomahawk	107	127	12,000	9	6.0	28	Jul 78
Beaver	107	17	340	4	5.5	50	Jul 78
Beaver (Tomahawk)	100	6	1,160	N/A	N/A	N/A	N/A
Drain	100	14	2,080	N/A	N/A	N/A	N/A
Sandy	91	36	3,014	N/A	N/A	N/A	N/A
McCabe	80	163	10,074	15	6.1	48	Jul 84
Little	76	4	894	N/A	N/A	N/A	N/A
Feely	76	11	1,600	6	6.3	28	Jul 78
Webber	70	39	5,093	17	6.0		Oct 71
Sandy	30	82	5,974	20	6.0	37	Oct 71
Halfway	100	13	1,560	N/A	N/A	N/A	N/A
Marsh	22	6	1,480	N/A	N/A	N/A	N/A

[a] From Lake Survey Reports - N.S. Dept. of Lands and Forests and Dept. of Fisheries and Oceans.

Table 4. Fish species occurrence, as indicated by surveys of the lakes, in the Sackville River watershed.[a]

Lake	White sucker	American eel	Speckled trout	Yellow perch	White perch	Golden shiner	Common shiner	Banded killifish
Pentz	X	X	X	X	X	X		
Lewis	X			X		X		
Tomahawk	X			X				
McCabe	X	X	X	X			X	
Beaver (Thompson Run)				X				
Bottle			X					
Webber	X	X						
Sandy	X	X	X	X		X		X
Little Feely	X	X						X

[a] From Lake Survey Reports - N.S. Dept of Lands and Forests and Dept. of Fisheries and Oceans (on file).

Table 5. Monthly water quality data (pH and conductivity) collected at two locations on the Sackville River 1984 and 1985[a].

Date	DND PROPERTY			Old Windsor Road		
	pH	Water temperature (°C)	Conductivity ($\mu s \cdot cm^{-1}$)	pH	Water temperature (°C)	Conductivity ($\mu s \cdot cm^{-1}$)
Jan 18 85	6.00		60	5.05		59
Feb 18 85	6.0		69.0	5.05		68
Mar 18 85	5.68		78.0	4.59		47
Apr 27 84	5.55			4.82		39
17 85	5.85		65.0	4.75		48
May 29 84	5.85		47.0	5.0		41
23 85	6.33		66.0	5.00		46
Jun 28 84	6.37		42.0	4.76		40
19 85	5.90		60.0	4.70		37
Jul 18 84	6.35		45.0	5.2		42
17 85	5.66		50.0	5.03		44
Aug 28 84	6.33	24.0	48.0	4.78	21.0	60
12 85	5.98		47.0	4.90		45
Sep 25 84	5.98	17.0	49	4.85	15.0	49
23 85	6.2		53	4.7		52
Oct 26 84	6.2	10.0	52	5.3	10.0	51
21 85	6.15		56			
Nov 23 84	5.93		56	4.97		63
14 85	6.30		58	4.39		55
Dec 17 84	6.25		62	4.5		55
85						

[a] Water samples collected by Dave Scott, analyzed by Inland Waters Directorate, Moncton and made available by Wes White.

Table 6. Number of fish captured by survey-removal method during electrofishing on the Sackville River, 1979.

Site number Location	Atlantic salmon fry	Atlantic salmon parr	Brook trout fry	Brook trout parr	American eel	White sucker	Lake chub	Brown bullhead	Banded killifish	Common shiner
1 Bedford (Opposite Rifle Range)	2	0	0	0	2	8	2	0	1	0
2 Bedford (Upstream Rifle Range)	28	0	0	0	29	13	2	0	0	0
3 Middle Sackville (Farm)	1	0	0	0	12	5	1	0	1	0
4 Middle Sackville (Gravel pit)	0	0	0	0	6	10	2	1	0	0
5 Lucasville Road (Below Heflers Mill)	0	0	0	0	27	2	3	1	2	2

Table 7. Miscellaneous electrofishing site characteristics, Sackville River 1979.

Site number Military grid	Date	Area (m^2)	Water temperature (°C)	Mean depth (cm)	Mean width (m)	Water conductivity ($\mu s \cdot cm^{-1}$)
1 475545	September 25	120	N/A	N/A	N/A	N/A
2 476548	September 25	210	17.0	20	12	50
3 452555	September 26	217	17.5	40	9	42
4 441565	September 25	214	19.5	70	10	45
5 436578	September 26	204	15.2	7	13	42

Table 8. Number of fish captured by spot-checking method during electrofishing on the Sackville River, 1985.

Site number Location	Numbers of fish/10 min of electrofishing				
	Brook Trout		American eel	White sucker	Banded killifish
	fry	parr			
6. Lewis Lake tributary	0	0	3	2	0
7. Main Sackville River	0	1	15	5	0
8. Main Sackville River	0	0	14	8	2
9. Upper main Sackville River	0	0	3	0	0
10. Upper main Sackville River	1	1	5	4	0
11. Little Sackville River	0	0	0	0	0

Table 9. Miscellaneous spot-checking data collected during electrofishing on the Sackville River, 1985.

Site number (Military grid)	Stream order	Area (m^2)	Water temp. (°C)	Mean depth (cm)	Mean width (m)	pH	Water cond. ($\mu s \cdot cm^{-1}$)	Bottom substrate S S G C B[b]	Shade (%)	Riffle/ run (%)
Sackville River										
6 (487630)	3	318	25.0	25.0	10.6	5.5	44	10 0 0 10 80	75	20/80
7 (381631)	3	334	23.0	16.7	5.1	4.8	55	0 0 0 0 100	50	0/90
8 (376647)	3	518	22.5	12.0	8.1	5.0	35	20 0 0 10 70	25	20/60
9 (372678)	3	365	18.0	21.0	6.4	5.1	40	40 5 15 0 40	50	10/30
10 (372700)	3	420	23.0	16.9	5.6	4.9	35	20 20 30 10 10	25	10/10
Little Sackville River										
11 (456567)	2	320	25.0	8.0	5.0	6.6	248	30 0 10 40 20	25	20/80

[a] Welcomme, R.L. River basins. FAO Tech. Paper 202. 60 p.
[b] Percentage of silt, sand, gravel, cobble, boulder, or bedrock.

Table 10. Water quality data collected during bioassay testing on the Sackville River, 1985.

Date	Water temperature (°C) Max.	Min.	pH test	pH control	Water level (cm)	Mortality
April 22	7.5[a]		6.02	6.13	31	0
April 23	10	5	6.00	6.07	29	0
April 24	6	4	5.95	6.13	27	0
April 25	8	5	5.80	6.00	25	0
April 26	11	6	5.80	5.70	23	0
April 27	12	7	6.25	6.19	22	0

[a] 1200 hrs.

Table 11. Length and weight data of hatchery test smolt (age 1+) used during bioassay testing on the Sackville River, 1985.

Cage No.	Fork length (cm) No	Mean	SD	Live weight (gm) No	Mean	SD	
1	20	12.2	1.17	20	19.1	5.40	Test cage
2	20	12.5	1.09	20	19.9	6.12	Test cage
3	20	11.8	0.96	20	17.0	4.28	Test cage
4	20	12.4	1.28	20	18.9	6.97	Control cage
5	20	12.3	1.16	20	17.7	5.95	Control cage
6	20	12.3	1.29	20	18.1	7.05	Control cage
Mean		12.3			18.3		
SD		0.24			6.18		

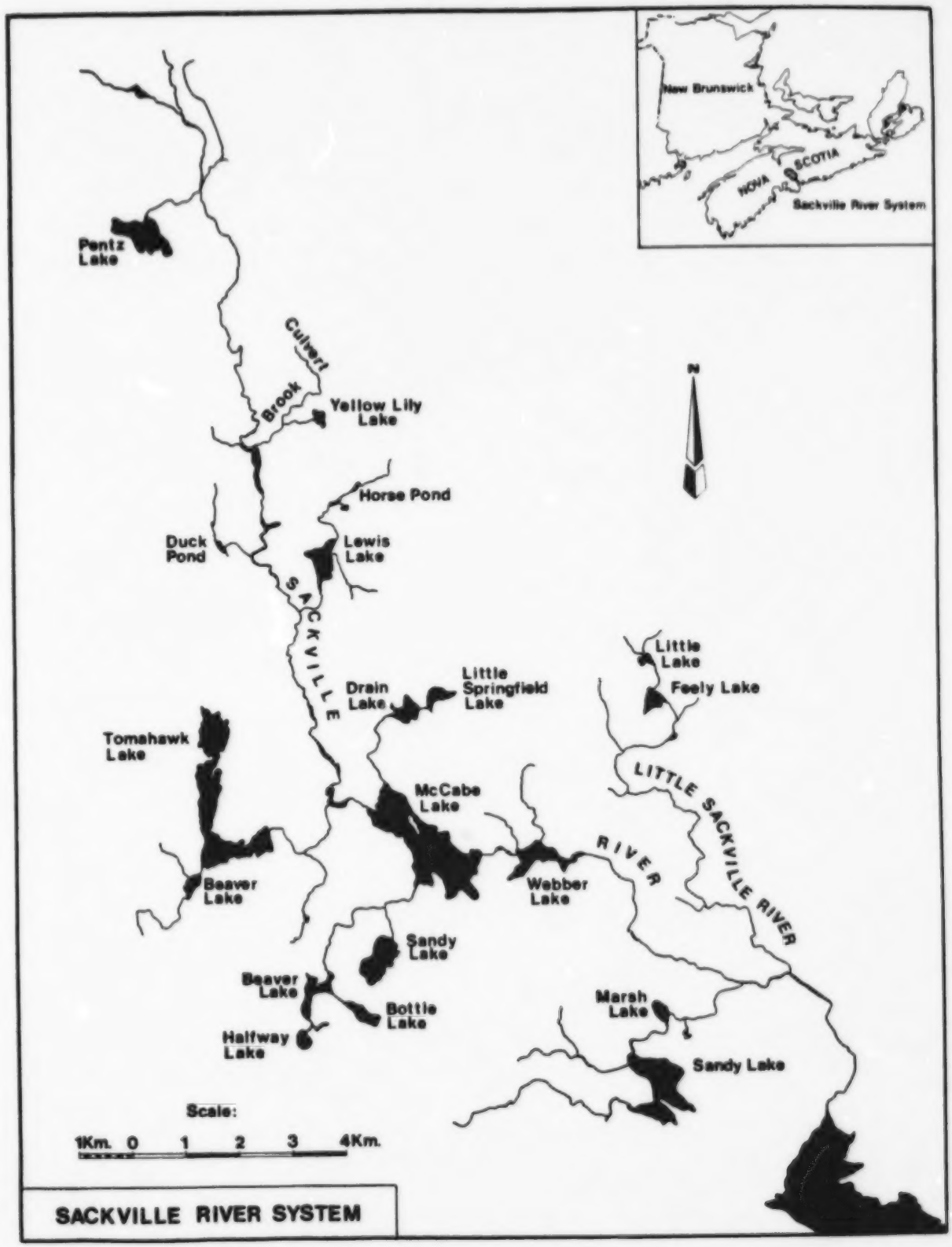

Fig 1. Map of the Sackville River watershed.

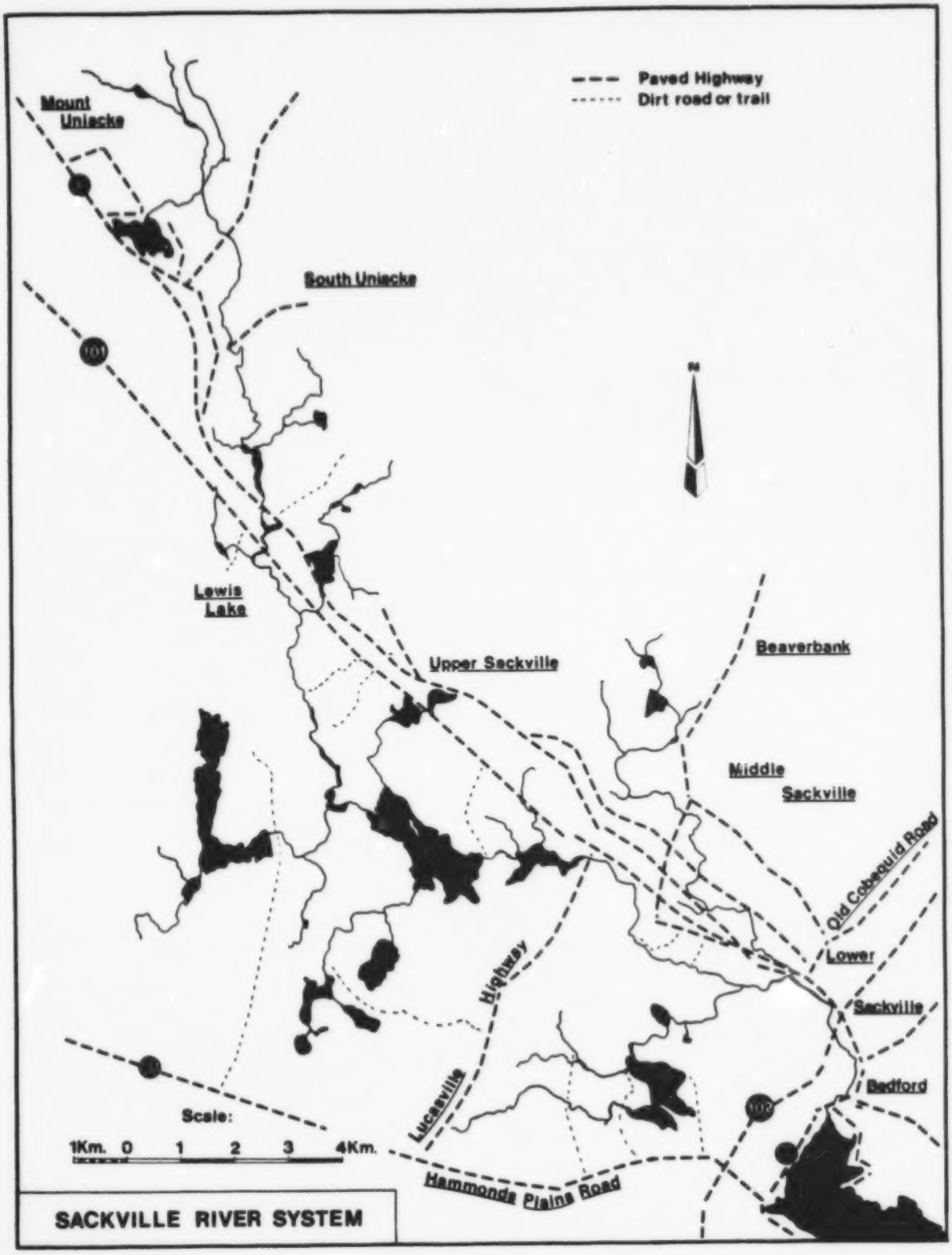

Fig. 2. Map of the access roads in the Sackville River watershed.

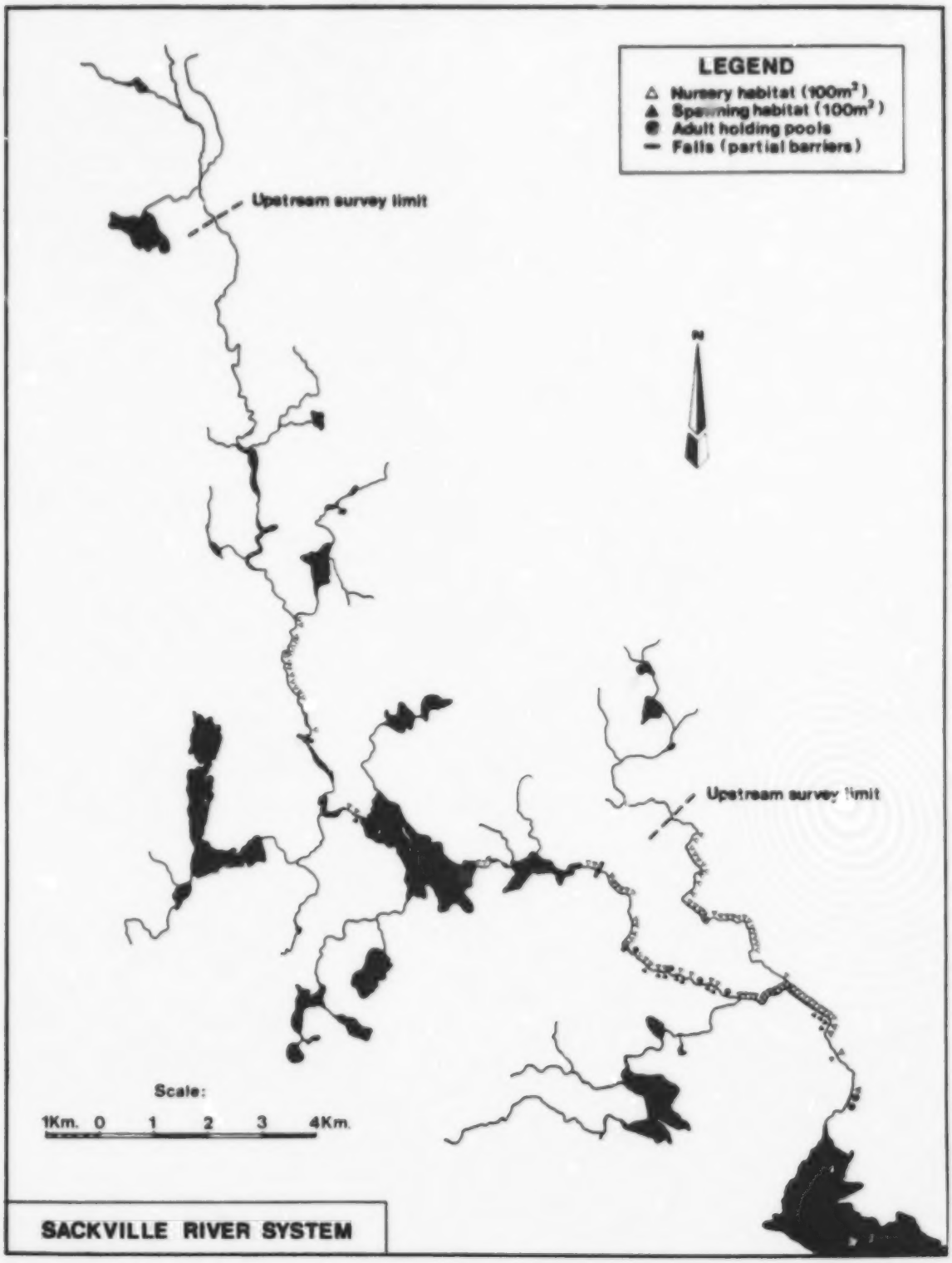

Fig. 3. Map showing the extent of nursery and spawning areas suitable for Atlantic salmon in the Sackville River.

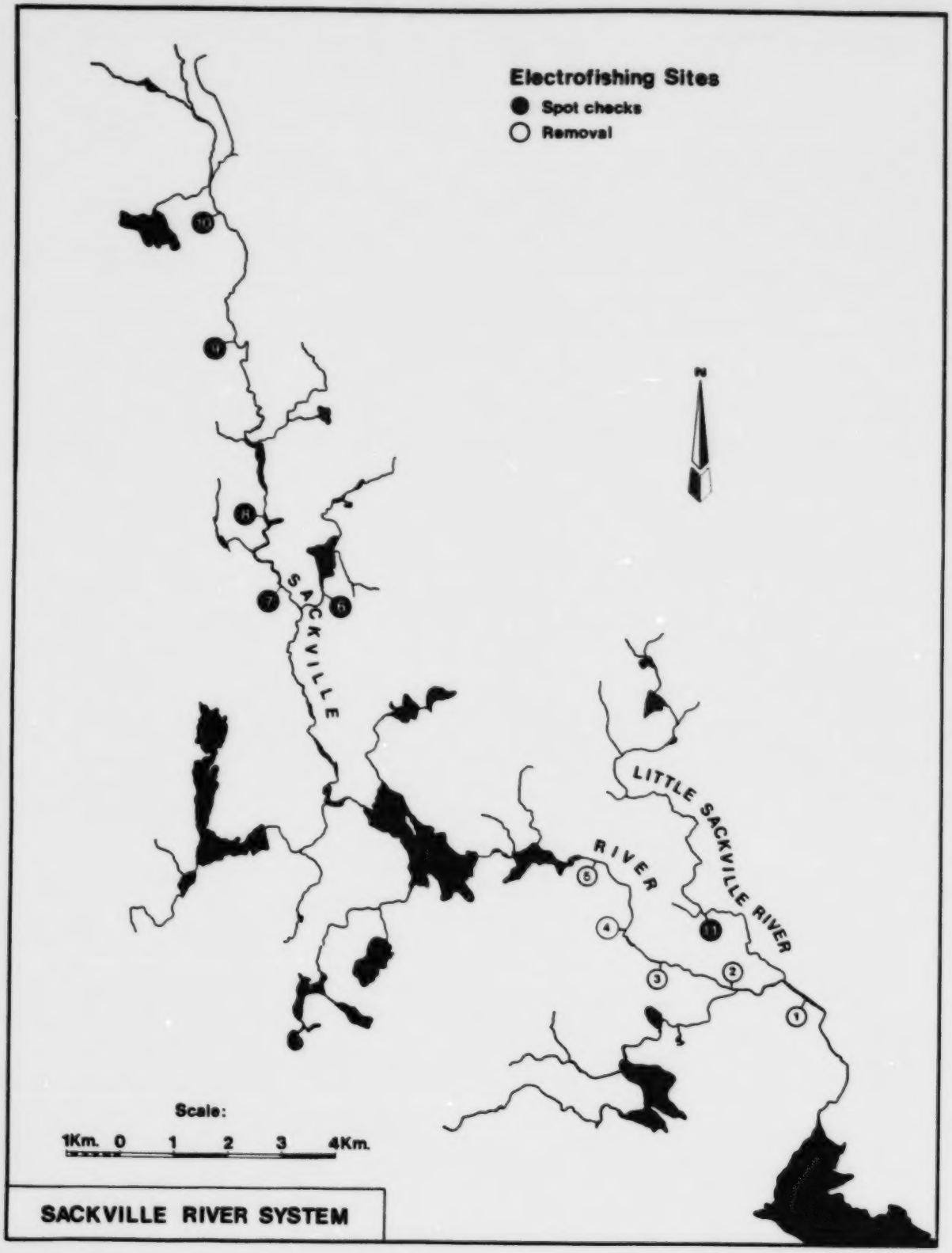

Fig. 4. Map showing the location of electrofishing sites, Sackville River and tributaries, 1979 and 1985.

Fig. 5. The main Sackville River looking downstream from the No. 102 highway bridge at Bedford, N.S.

Fig. 6. The main Sackville River showing a large holding pool in the town of Bedford, N.S.

Fig. 7. The main Sackville River upriver from the confluence of the Little Sackville River showing a predominately riffle water surface and a gravel and cobblestone substrate.

Fig. 8. The main Sackville River upriver from the confluence of the Little Sackville River showing a riffle and flat water surface.

Fig. 9. The main Sackville River downstream from Webber Lake showing stream modifications caused by gravel removal.

Fig. 10. The main Sackville River downstream from Webber Lake showing a section of the stream used for gravel removal and the disposal of garbage.

Fig. 11. The main Sackville River above the confluence of the Little Sackville River showing a shallow pool and run.

Fig. 12. The main Sackville River between Webber and McCabe Lakes showing a flat water surface area.

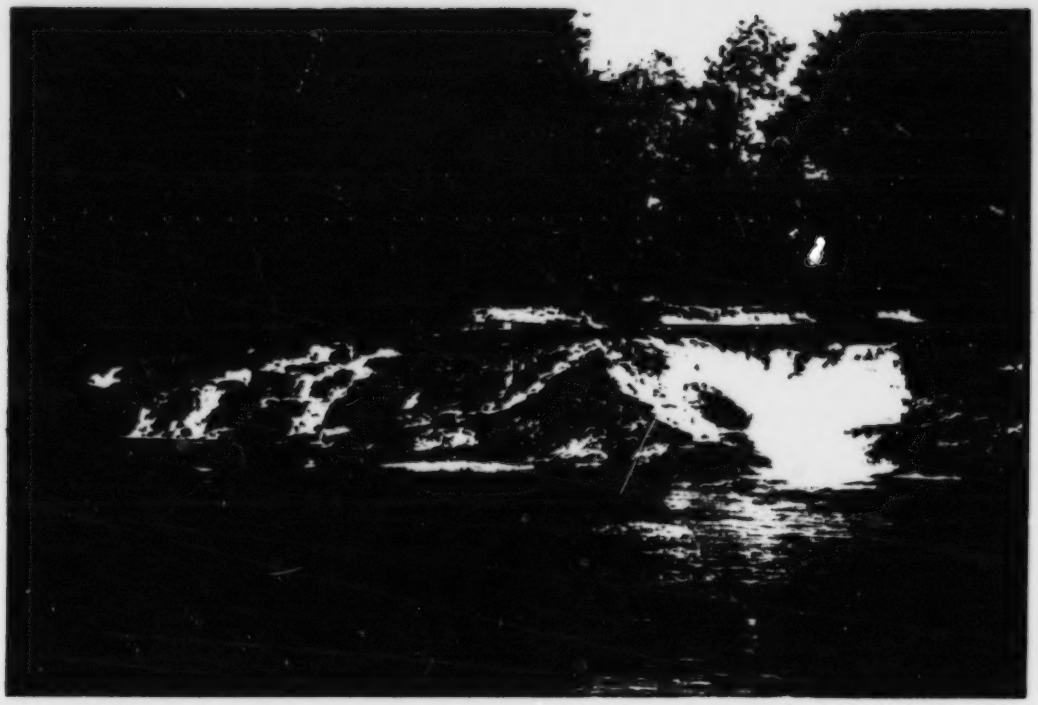

Fig. 13. A small obstruction (falls) on the main Sackville River downstream of Webber Lake (Heflers Mill).

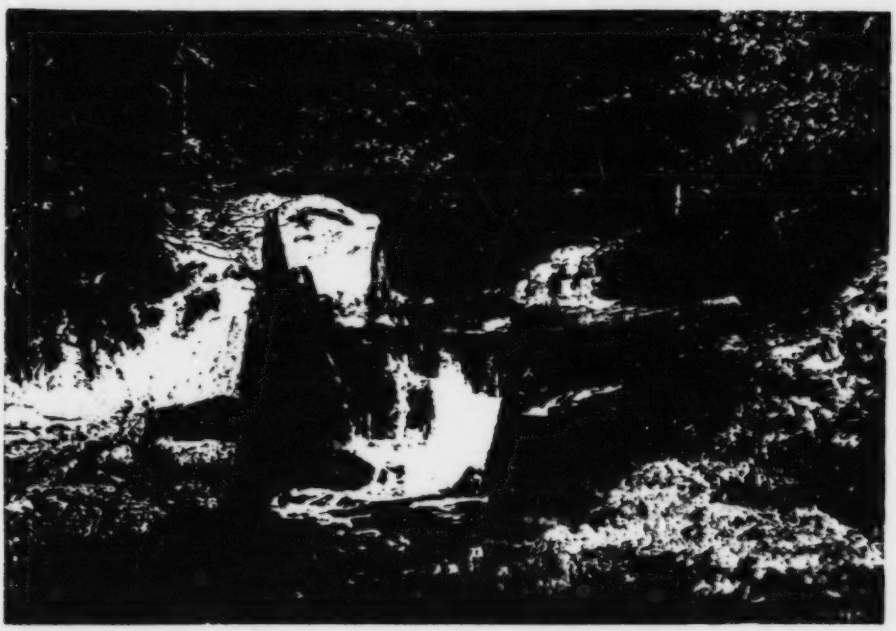

Fig. 14. A small obstruction (falls) on the main Sackville River upriver of McCabe Lake.

Fig. 15. The main Sackville River upstream of McCabe Lake showing the cobble and boulder substrate typical of this section of the stream.

Fig. 16. The main Sackville River downstream below Pentz Lake showing the stillwater and meadow typical of the headwater drainage areas.

Fig. 17. Little Sackville River during low flow conditions showing a mainly cobble substrate.

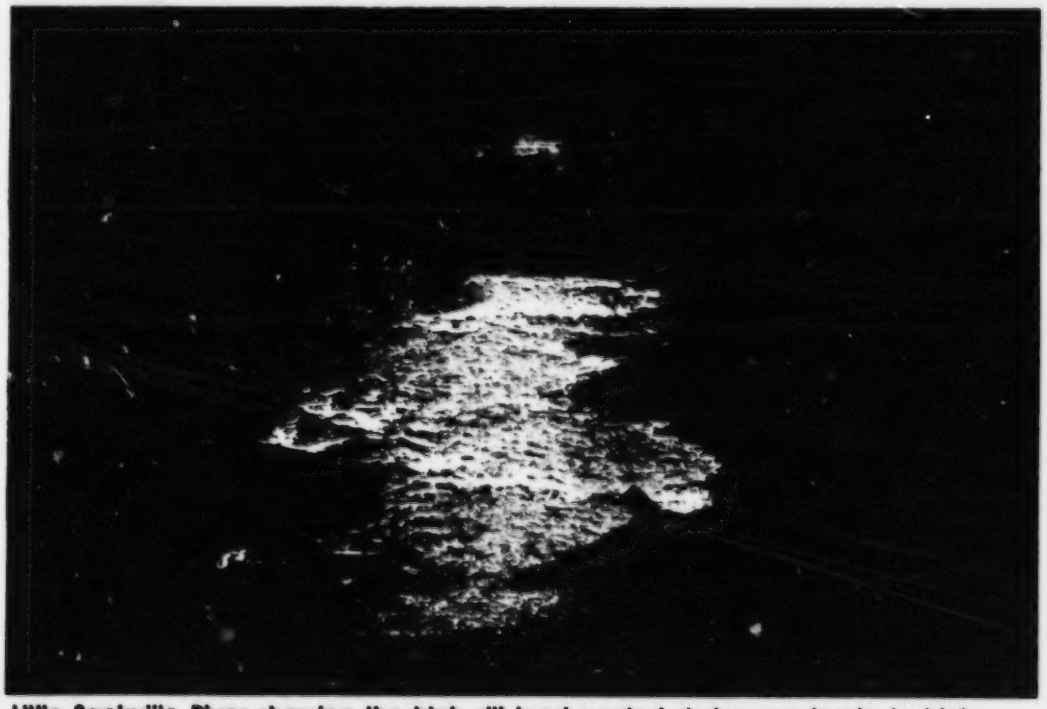

Fig. 18. Little Sackville River showing the high silt load carried during moderate to high flows.

Appendix A. Definitions of substrate type, stream characteristics, and nursery and spawning habitat taken from Gray et al. (1982).

Substrate Type	Particle size (mm)
Silt	Small grade sand or washed out topsoil. Organic detritus. Microscopic under 1 mm.
Sand	1 - 5
Gravel	6 - 102
Cobble	103 - 305
Boulder	over 306
Bedrock	Outcropping of exposed rock or ledge

Stream Characteristics

Riffle: shallow, fast flowing broken water
Run: deep, fast flowing unbroken water
Flat: shallow, slow flowing water
Pool: deep (deeper than average depth of section, usually wider)
Stillwater: deep, slow flowing water. Usually silt or mud covering bottom substrate.

Nursery Habitat Definitions

"Good" Nursery
- cobble and boulder in substrate greater than 50% with at least 20% cobble
- minimum 70% riffle and run
- minimum depth 18-20 cm

"Fair" Nursery
- cobble and boulder in substrate 10-49%
- minimum 10% cobble
- minimum 70% riffle and run

"Marginal" Nursery
- less 10% cobble/boulders
- flats, pools, stillwaters

Spawning Habitat Definitions

"Good" Spawning
- less 10% sand
- 40-80% gravel
- 10-40% cobble
- occasional boulders
- gradients 0.5%

"Marginal" Spawning
- greater than 10% silt/sand but less than 20%
- less than 40% gravel with 50-90% cobble/boulder
- less than 50% riffle
- areas with good spawning substrate but greater than 20% vegetation
- areas with high compaction and low permeability
- areas with good spawning substrate but over 1 m depth

Marginal areas would generally be used for spawning but egg survival would be low.

Appendix B. Estimated stream substrate and water surface characteristics (as percentage of total) of the main Sackville River, 1986.

Section 100 m	Substrate (%)						Water characteristics (%)					Mean depth (cm)
	silt	sand	gravel	cobble	boulder	bed-rock	riffle	run	flat	still-water	No. of pools	
1	10	10	10	10	60	0		50	50			90
2	0	0	0	0	100	0	100					67
3	5	5	20	50	20	0	50	50				61
4	50	10	10	20	10	0				100		350
5	100	0	0	0	0	0				100		350
6	100	0	0	0	0	0				100		350+
7	20	10	20	40	10	0				100		350+
8	40	10	50	0	0	0			50	50		350+
9	100	0	0	0	0	0	5			95		300
10	100	0	0	0	0	0				100		300
11	40	40	15	5	0	0		50		50		70
12	30	0	70	0	0	0				100		100+
13	5	25	5	10	55	0		5	95			60+
14	0	50	40	10	0	0		100				44
15	10	50	10	20	10	0			100			60
16	0	50	50	0	0	0	50	50				50
17	0	40	60	0	0	0	50	50				50
18	0	20	60	10	10	0	50	50			1	30
19	0	20	80	0	0	0	50	50				50
20	0	20	20	50	10	0	100					30
21	30	30	30	10	0	0		60	40			43
22	15	15	60	10	0	0		90	10			51
23	30	30	30	10	0	0	50	50				50
24	10	20	60	0	0	0	10	90				44
25	15	15	50	20	0	0		100				47
26	30	30	30	10	0	0	90	10				36
27	0	5	70	20	5	0	100					31
28	0	0	80	20	0	0	100					34
29	5	10	35	50	0	0	100					32
30	5	10	50	30	5	0	60	40				32
31	5	5	45	45	0	0	70	30				34
32	5	10	50	35	0	0	100					39
33	0	0	10	35	55	0	100					33
34	5	10	30	50	5	0	100					30
35	0	20	20	40	20	0	50	50				35
36	0	10	30	50	10	0	100					65
37	0	0	5	45	50	0	85		15			35
38	0	10	35	40	15	0	60	40				41
39	0	5	10	50	35	0	50	50				44
40	0	0	10	45	45	0	100					36
41	10	10	25	40	15	0	100					31
42	10	10	35	30	15	0		100				48
43	10	10	20	45	15	0	10	90				50
44	5	5	20	40	30	0	100					36
45	10	20	10	50	10	0	100					31
46	5	5	30	40	20	0	50	50				39

Appendix B. (continued)

Section 100 m	Substrate (%)						Water characteristics (%)					Mean depth (cm)
	silt	sand	gravel	cobble	boulder	bed-rock	riffle	run	flat	still-water	No. of pools	
47	5	5	25	55	10	0	100					46
48	50	50	0	0	0	0		50		50		100
49	80	20	0	0	0	0			100			100
50	100	0	0	0	0	0			100			100
51	100	0	0	0	0	0				100		100
52	0	100	0	0	0	0		100				100
53	0	70	20	10	0	0	10			90		100
54	0	15	60	20	5	0	50	50				24
55	10	20	10	60	0	0				100		100
56	0	0	30	40	30	0	100				1	20
57	10	15	40	15	20	0	100				1	32
58	10	10	40	40	0	0	100					33
59	10	10	30	50	0	0	100					30
60	5	5	20	55	15	0	100					37
61	0	0	25	45	30	0	100					42
62	0	0	10	50	40	0	50	50				33
63	0	0	20	65	15	0	85	15			1	27
64	5	5	10	75	5	0	100				1	32
65	30	30	15	15	10	0				100		43
66	15	15	35	35	0	0	90	10				40
67	0	0	10	50	40	0	100					38
68	5	5	0	55	35	0		100				39
69	5	5	0	20	70	0		100				95
70	5	5	5	50	35	0		100				54
71	5	20	45	20	10	0		50	50			59
72	5	10	85	0	0	0		75	25		2	40
73	5	10	85	0	0	0		75	25			40
74	5	15	40	35	5	0	100				1	46
75	0	10	20	40	30	0	100					39
76	0	0	0	40	60	0	100					44
77	0	0	0	25	75	0	100					39
78	0	0	10	40	50	0	100					37
79	0	0	0	10	90	0	100					41
80	0	0	20	30	50	0	100					37
81	0	0	10	20	70	0	100					32
82	5	5	10	35	45	0	100					48
83	0	0	5	30	65	0	100					43
84	0	0	0	20	80	0	100					49
85	0	5	10	35	50	0	80	20				36
86	0	0	10	25	65	0	100					36
87	0	0	0	0	10	90	10	90				35
88	0	0	0	10	10	80	10	90				29
89	0	0	0	5	10	85	70	30				
90	5	5	5	5	55	25	100					29
91	0	0	0	0	100	0	100					36
92	5	10	10	20	55	0	50	50			1	41
93	0	0	0	5	10	85	100					34

Appendix B. (continued)

Section 100 m	Substrate (%) silt	sand	gravel	cobble	boulder	bed-rock	Water characteristics (%) riffle	run	flat	still-water	No. of pools	Mean depth (cm)
94	0	0	10	40	40	10	100					20
95	20	20	30	20	10	0		100				44
96	30	30	0	10	0	30		50		50		51
97 to 108					Webber Lake							
109	0	10	20	45	25	0	100					50
110	30	30	10	20	10	0	0		100			50
111	30	30	10	20	10	0	100					50
112	15	5	0	10	75	0	0		100			30
113	0	0	0	10	60	30	100					42
114	0	0	10	35	55	0	100					29
115	5	5	20	30	40	0	100					34
116 to 140					MacCabe Lake							
141	0	10	30	40	20	0		100				
142	0	10	30	40	20	0	100					
143 to 152										100		
153	0	0	0	60	30	10	20	80			1	12
154 to 165										100		
166	0	0	5	50	40	5	50	50				
167 to 175										100		
176	0	0	10	50	40	0	80	20				9
177	0	0	10	50	40	0	80	20				
178	0	0	10	35	55	0	50	50			1	15
179	0	0	10	35	55	0	50	50				15
180	0	0	10	35	55	0	50	50				
181	0	0	0	20	80	0	100					12
182	0	0	10	50	40	0	50	50			2	
183	0	0	20	50	30	0	50	50				
184	0	0	20	50	30	0	50	50				
185	0	20	20	50	10	0	50	20	30			15
186	0	0	20	40	40	0	30	30	40			
187	0	0	10	40	50	0	50	50				
188	0	0	5	10	60	25	10	90				
189	0	20	30	40	10	0	100					23
190	0	0	20	50	30	0	100					15
191	0	0	20	50	30	0	80	20			1	7

Appendix B. (continued)

Section 100 m	Substrate (%)						Water characteristics (%)					Mean depth (cm)
	silt	sand	gravel	cobble	boulder	bed-rock	riffle	run	flat	still-water	No. of pools	
192	0	0	20	50	30		80	20				1
193	0	0	10	30	40	20	80	20				
194	0	0	0	20	80	0	50	50				5
195	0	0	20	20	80	0	50	50				5
196	0	0	0	20	80	0	50	50			1	8
197	0	0	0	40	60	0	50	50			1	7
198 to 239	Highway No. 1 bridge at Section 216									100		
240	60	0	0	10	30	0	80		20		1	40
241	60	0	0	10	30	0	80		20			40
242	60	0	0	10	30	0	80		20			40
243	20	5	5	10	20	40	80		20			37
244	20	5	5	10	20	40	80		20			37
245	20	5	5	10	20	40	80		20			37
246	50	0	15	25	10	0			100			40
247	50	0	15	25	10	0			100			40
248	50	0	15	25	10	0			100			40
249	20	0	0	40	40	0	60	40				40
250	20	0	0	40	40	0	60	40				40
251	20	0	0	40	40	0	60	40				40
252	30	5	15	30	20	0	5		75	20		31
253	30	5	15	30	20	0	5		75	20		31
254	30	5	15	20	20	0	5		75	20	1	31
255	40	0	10	10	40	0	50				2	24
256	40	0	10	10	40	0	50					24
257	40	0	10	10	40	0	50					24
258 to 264										100		100
265	50	50	0	0	0	0						100
266	30	10	5	30	25	0		50	50			100
267	30	10	5	30	25	0				100		100
268 to 280										100		100
281	30	10	5	30	25	0				100		100
282	20	30	0	0	50	0			100			17
283	5	5	20	70	0	0	50	50				90

Appendix C. Estimated stream substrate and water surface characteristics (as percent of total) of Little Sackville River, 1986.

Section 100 m	Substrate (%)						Water characteristics (%)				No. of pools	Mean depth (cm)
	silt	sand	gravel	cobble	boulder	bed-rock	riffle	run	flat	still-water		
1	30	25	20	15	10	0		25	75			19
2	20	20	5	20	35	0			100			21
3	10	10	5	40	35	0	50		50			12
4	30	20	25	20	5	0	100					10
5	40	20	15	10	15	0	30		70			11
6	30	20	10	20	20	0	10		90			17
7	60	20	20	0	0	0			100			23
8	30	15	45	10	0	0			100			16
9	35	5	55	5	0	0	50	30	20			11
10	35	10	20	30	5	0			100			14
11	30	15	5	35	15	0	50		50			13
12	10	10	30	35	15	0	30		70			7
13	15	10	20	40	15	0	100					9
14	15	10	15	40	20	0	40		60			10
15	30	10	10	30	20	0	30		70			12
16	20	10	5	40	25	0	50		50			15
17	30	5	30	30	5	0	100					13
18	25	15	5	55	10	0	100					7
19	20	10	5	60	5	0	100					8
20	20	15	20	35	10	0	100					9
21	30	15	5	40	10	0	100					11
22	15	15	0	10	60	0	100					12
23	10	15	5	15	55	0	100					9
24	20	20	0	5	55	0	50	50				10
25	60	5	25	10	0	0	50		50			14
26	35	10	20	10	25	0			50	50		16
27	10	15	60	15	0	0		50	50			14
28	20	5	15	35	25	0	100					11
29	25	10	10	25	30	0	100					11
30	5	5	0	20	70	0	100					11
31	10	10	0	40	40	0	100					9
32	30	30	30	10	0	0			100			9
33	5	5	15	30	30	15	100					8
34	5	0	5	5	45	40	100					11
35	20	5	30	35	10	0		50	50			11
36	25	25	20	30	0	0	50	50				6
37	15	15	40	30	0	0	50	50				9
38	20	10	30	30	10	0	100					8
39	10	10	20	50	10	0	50	50	culverts			12
40	10	10	10	40	30	0	0					12
41	5	5	15	35	40	0		100				12
42	5	10	20	35	30	0	100					9
43	15	15	25	30	15	0	50	50				7
44	10	0	5	70	15	0		100				13
45	15	0	10	45	30	0	100					17
46	10	5	0	40	45	0	100					10
47	20	0	5	60	15	0	50		50			6
48	40	0	0	50	10	0	50		50			27
49	40	0	0	50	10	0	50		50			23
50	100	0	0	0	0	0				100		23
51	10	10	60	10	10	0		50	50			16

Appendix D. Atlantic salmon nursery and spawning habitat measurements and remarks, by survey section, main Sackville River, 1986.

Section	Nursery			Spawning		
(100 m)	Good	Fair	Marginal	Good	Fair	Remarks
1		1,150	1,150			Tidal, estuary, railway and two highway bridges.
2			1,150			Bedford Commercial District Fish Hatchery Park.
3		900			900	Heavy substrate, riffle and runs.
4			1,800			Holding pool. Large black willow trees.
5			1,600			Holding pool. Parking lot.
6			1,450			Holding pool. Commercial development.
7			1,500			Holding pool. Vertical retaining wall.
8			2,200			Holding pool. Parking lot.
9			1,500			Holding pool. Office towers, lawn.
10			1,900			Holding pool. Poor cover.
Subtotal		2,050	14,250		900	
11			1,800			Sunnyside area. Garbage in river.
12			2,000			Gravel compacted and silted. Garbage.
13			1,700		200	Gravel highly compacted with sand and silt.
14			2,100			Below access bridge to Bedford Shopping Mall.
15			1,700			Large concrete piers in river, both banks.
16			1,500			Very fine sand mixed with gravel. Bank erosion.
17			1,500			Alders lining both banks. Sandy.
18			1,500		1,500	Alders. One small poor quality pool.
19		2,000		2,000		Unstable ground & sand islands. Continuation previous pool.
20	2,700				2,700	Bicentennial highway overpass.
Subtotal	2,700	2,000	13,800	2,000	4,400	
21			1,700			Alders lining banks. Poor cover.
22			1,700			Alders lining banks. Poor cover.
23		1,600				Gravel bars. High % sand and gravel.
24	1,450					Drain from reservoir. No evidence of pollution.
25	1,400					DND range, wood bridge.
26			1,650			Dirt road crossing river.
27	1,800			1,800		Spawning, gravel.
28	1,800			1,800		Gravel highly compacted.

Appendix D. (continued)

Sections	Nursery			Spawning		
(100 m)	Good	Fair	Marginal	Good	Fair	Remarks
29	2,000			2,000		Substrate material gradually increasing in size.
30	2,100			2,100		Silt running in from Little Sackville. Power transmission line crossing river.
Subtotal	10,550	1,600	5,050	7,700		
31	2,100			2,100		Culvert discharge. Fine silt from Little Sackville River.
32	1,900			1,900		Gradual increase in size, compaction.
33	1,700					Small brook. 19°C at 1430 hrs.
34	2,200				2,200	Good nursery.
35	2,000			2,000		Entry of Little Sackville River.
36	2,200			2,200		Good nursery and spawning areas.
37	1,500		300	1,500		Mainly rapids, water swift and rough.
38	1,750			1,750		Good nursery and spawning, small island.
39	1,700			1,700		Good nursery and spawning.
40	2,500			2,500		Large boulders. Gravel bars.
Subtotal	19,550		300	15,650	2,200	
41	2,300				2,300	Should be good spawning but high gravel compaction.
42	2,000				2,000	Continuation of high gravel compaction problem.
43	1,800				1,800	Continuation of high gravel compaction problem.
44	2,000			2,000		Excellent gravel but highly compacted with sand.
45	2,300					Two islands. Instream gravel highly compacted. Gravel bars alon shore.
46	2,000			2,000		Gravel highly compacted.
47	1,000			1,000		Gravel highly compacted. Island. Debris in river.
48			1,350			Muddy and deep water. Remains of old beaver dam.
49			1,500			Two islands. Gravel bars along shore. Instream gravel compacted.
50			1,400			Mud bottom.
Subtotal	13,400		4,250	5,000	6,100	
51			1,400			Mud bottom.
52			1,000			Sand highly compacted. Island. Branches in river.

Appendix D. (continued)

Sections	Nursery			Spawning		
(100 m)	Good	Fair	Marginal	Good	Fair	Remarks
53			900			Two islands.
54	1,600			1,600		Gravel compacted.
55			1,600			Old bridge, island. River braided.
56	1,800			1,800		Two islands. Swift water.
57			1,800			Rapids. Garbage and logs in stream.
58		1,700			1,000	Fallen tree in river. Old gravel pit.
59		1,000			1,000	Two islands. Indication of pollution. Brown algae.
60	1,200			1,200		Rock wall to divert water for cattle.
Subtotal	4,600	2,700	6,700	4,600	2,000	
61	1,100			1,100		Rapids. Heavily eroded bank. Fallen trees instream.
62		1,300				Rapids.
63	1,000		315	1,000		Pool with poor shade and cover. Island.
64	1,600			1,600		Very small pool.
65			1,800			Flat area.
66	1,300					Island.
67	1,800			1,800		Two junked cars in river. Pockets of slow water with silt & sand.
68	1,400					Access road by river. Car bodies, tires, and junk in river.
69		900				Rapids.
70		950				Torrential rapids.
Subtotal	8,200	3,150	2,115	5,500		
71		1,100			1,100	Sand and gravel, heavily compacted.
72		1,500	500	1,500	500	Heavily braided, log jams, overgrown alders, sand & gravel heavily compacted.
73 & 74	2,000				2,000	Deep pool along bank.
75	1,300				1,300	Light rapids.
76	1,100					Fallen trees and debris in river gravel bars.
77		1,400				Log jams, heavily eroded banks.
78	1,300				1,300	Rapids. Garbage in river eroded banks.
79		1,100				Small brook. Rapids.

Appendix D. (continued)

Sections	Nursery			Spawning		
(100 m)	Good	Fair	Marginal	Good	Fair	Remarks
80	1,100				1,100	Good parr habitat.
Subtotal	6,800	5,100	500	1,500	7,300	
81		1,500			1,500	Fallen tree in river.
82	1,700				1,700	Gravel bar.
83	1,400					Gravel bar.
84	1,400					Heavy material - boulders.
85	1,400				1,400	Clear cut areas.
86	1,500				1,500	Good parr habitat.
87			2,100			Bedrock steps.
88			2,400			Bedrock.
89			1,600			Bedrock.
90		1,350				Algae, excessive organic material in river. Saw mill pollution.
Subtotal	7,400	2,850	6,100		6,100	
91		1,300				Large boulders, sawdust pile.
92	1,700				1,700	Sawmill to below falls.
93			1,800			3 meter falls, bedrock.
94	1,600				1,600	Bedrock.
95		1,600				Watergrass. Run with gradient gradually decreasing.
96			1,500			End of stream. Beginning of Webber Lake.
Subtotal	3,300	2,900	3,300		3,300	
97			Webber Lake			
108						
109	1,300				1,300	Stream braided. Slow riffles.
110			6,000			Flat section. Alders and grass.
111						Combined with section 110. Island.
112			5,000			Flat section. Choked with grass.
113	1,100					Riffle with exposed bedrock.
114	1,100				1,100	Small patches of gravel. Clear cutting.

Appendix D. (continued)

Sections (100 m)	Nursery			Spawning		Remarks
	Good	Fair	Marginal	Good	Fair	
115	1,500			1,500		Small island. Good spawning in small areas.
Subtotal	5,000		11,000	1,500	2,400	
116 to 140		McCabe Lake				
141	800			800		Scattered large boulders. Good scattered spawning.
142	2,400				2,400	Spawning very scattered.
143 to 152			40,000			Stillwater.
153 to 165			26,800			Second run. Possibly scattered spawning but very marginal. Stillwater - Second stillwater.
166	1,400				140	Falls (1.5 m) No barrier. Deep holes suitable for adult holding.
167 to 175			12,000			Stillwater.
176	1,200		1,500	500		Dense alders on river bank. Mainly stillwater.
177			1,500			Dense alders on river bank. Mainly stillwater.
178 to 180	1,750				87.	Large boulders with patches of scattered spawning.
181		800				Large boulders in stream.
182	1,800					4,200 m^2 pools, good holding.
183 to 184	1,600					Large boulders in river. (High percentage of instream vegetation.)
185	700			450		Good cover. 250 m^2 flat. Two islands.
186		500	300		500	Sticks and logs blocking stream.
187	600				600	Large boulders and scattered aquatic vegetation.
188	900					Moss covered boulders.
189	900				900	Scattered spawning of poor quality.
190	900				900	Very scattered spawning.
191 to 192	1,200			1,200		Cover provided by boulders.

Appendix D. (continued)

Sections	Nursery			Spawning		
(100 m)	Good	Fair	Marginal	Good	Fair	Remarks
193	450				450	Power line - junction Lewis Lake brook.
194 to 195		1,000				Stream covered with boulders.
196		800				Electrofished in 1985. Log & debris in river. Logging road.
197		700				800 m^2 pool.
198 to 239			210,000			Large stillwater. Lake like in section. Moderately deep (3 m). Suitable for holding adult fish. Good angling access. Rocky bottom. #1 Highway.
Subtotal	16,600	3,800	292,100	2,950	5,978	
240 to 242			1,560			Light layer of substrate above continuous bedrock.
243 to 245		1,040	260			Pool to bedrock.
246 to 248			2,070			Flat area. Alders both banks.
249 to 251		3,000				Large braided section in stream. Log jam on West Bank (right). Some grass cover.
252 to 254		69	1,311			Two log jams.
255 to 257			1,880			940 m^2 pool. Old road coming to bank. Garbage in river. Car parts
258 to 265			11,200			Slow stillwater. Mud and silt bottom.
266			830			Alders, hawthorne, sedge, long grass.
267 to 281			15,000			1.5 km of stillwater, with overgrown alders and a boggy shoreline.
282			830			Flat area, alders and spirea.
283	400				400	Possible spawning.
Subtotal	400	4,109	34,941		400	
Total	98,500	30,259	394,406	46,400	41,078	
% of total area	19%	6%	75%	9%	8%	

Total Nursery = 523,165 Total Spawning = 87,478

Appendix E. Atlantic salmon nursery and spawning habitat measurements and remarks, by survey section, Little Sackville River, 1986.

Sections	Nursery			Spawning		
(100 m)	Good	Fair	Marginal	Good	Fair	Remarks
1		200	600			High degree siltage. Wide bridge footing a barrier in low water.
2			700			Flat with moderate shade from alders.
3	250		250			Rock garden. Slow flowing. Pollution from building development. Algae, silt, lumber and styrofoam in stream.
4		500				Bottom extremely compacted.
5		210	490			Large boulders.
6		80	720			Rock garden. Flat with mud bottom.
7			700			Bottom very muddy.
8			600			Silt, gravel bars, styrofoam garbage, small brook, drainage ditch.
9			700			Some good gravel, buried in silt.
10			700			Indications of some flooding. Spawning gravel underneath layer of silt.
Subtotal	250	990	5,460			
11			500			Dry culvert, new home construction.
12	210		490			High degree of siltage.
13	700					Very shallow, high degree siltage.
14	300		400			Sand and silt. Plywood, carpet, sheet metal, garbage.
15	180		420			Bottom covered with silt and garbage.
16	300					Algae, silt and sand.
17		700				Heavy silt, water very low in river bed.
18	750					Sand and silt prevent this from being an excellent parr habitat.
19	900					Drainage ditch from highway.
20	900					Silt, algae, garbage.
Subtotal	4,240	700	1,810			
21	700					Rock garden. Plastic bags, algae and silt in stream.
22	750					Rock garden. Plastic bags, algae and silt in stream.
23	700					Rock bridge - barrier at low water. Water opaque. Algae, pollution. Paths along bank.
24	500					Algae and silt throughout. Lawn/shrubs.
25			600			Culvert with source of opaque water. ph-6.7
26			800			Silt, flat and stillwater.

Appendix E. (continued)

Sections	Nursery			Spawning		
(100 m)	Good	Fair	Marginal	Good	Fair	Remarks
27			600			Substrate covered with algae.
28	750					Highway overpass creates some shading.
29	750					Office building, houses, open field.
30	600					Algae, rock garden, pavement.
Subtotal	4,750		2,000			
31	500					Open area, water very low. Commercial property.
32			700			Drainage culvert from housing development.
33	800					Rock garden. Garbage, snowmobile, tins, hose, etc., in river.
34		1,100				Boulders in river.
35		250	250			Scrap iron in river. Open field.
36		200	200			Alders, algae, sand, silt. Commercial property.
37		450				Rock garden, gravel, small footbridge, residential homes.
38		700				Residential area.
39	450					½ area is culvert under Sackville Highway.
40	500					Water very low. Rock garden. Lawns.
Subtotal	2,250	2,700	1,150			
41	600					Rock garden. Water very low.
42	500				500	Water very low.
43		700				Water very low.
44	700					Mounds of backfill pushed into river.
45	700					Silt.
46	700					Silt.
47	350		350			Obstruction of stepping stones. Flatwater with suspended silt.
48	450		450			Aquatic grass in river, mud.
49	450		450			Mud, slow riffle, rock garden.
50			1,500			Mud, flatwater.
51			1,000			New homes, stepping stones, obstruction.
Subtotal	4,450	700	3,750		500	

Appendix E. (continued)

Sections	Nursery			Spawning		
(100 m)	Good	Fair	Marginal	Good	Fair	Remarks
Total	15,940	5,090	14,170		500	
(%)	45	15	40			Total Area Surveyed Little Sackville River- 35,200 m^2

Gravel Permeability Data
Sackville River

Appendix: F-1
Date: September 8, 1986
Location: Below bridge, 102 highway
Map No.: 11 D/12
Military Grid Reference: 476543
Temperature of Sample: 19°C

Sample Number	Adjusted volume pumped (ml)	Elapsed Time (secs)	Abstraction rate ($ml \cdot sec^{-1}$)	Permeability at observed temperature ($cm \cdot hr^{-1}$)	Standard permeability at 10°C ($cm \cdot hr^{-1}$)
1	75	31.3	2.4	132	108.2
2	175	31.0	5.7	420	344.4
3	75	31.9	2.4	132	108.2
4	5	30.5	0.2	100	82.0
5	10	30.4	0.3	100	82.0
6	90	30.6	2.9	172	41.0
7	125	30.4	4.1	287	235.3
8	45	29.5	1.5	100	82.0
9	15	30.3	0.5	100	82.0
10	15	30.2	0.5	100	82.0
11	115	30.6	3.8	260	213.2
12	45	30.1	1.5	100	82.0
					$\bar{X}$=136.8

Appendix: F-2
Date: September 8, 1986
Location: Below trailer court, Middle Sackville
Map No.: 11D/13
Military Grid Reference: 441565
Temperature of Sample: 19.0°C

Sample Number	Adjusted volume pumped (ml)	Elapsed Time (secs)	Abstraction rate ($ml \cdot sec^{-1}$)	Permeability at observed temperature ($cm \cdot hr^{-1}$)	Standard permeability at 10°C ($cm \cdot hr^{-1}$)
1	75	30.1	2.5	140	110
2	350	30.7	11.4	965	762
3	475	30.6	15.5	1,482	1,170
4	200	30.5	6.6	510	402
5	285	30.6	9.3	780	616
6	155	30.6	5.1	360	284
7	240	30.4	7.9	640	505
					$\bar{X}$ = 550